

# Comparing Apples and Pears: the Hidden Diversity of Central African Bush Mangoes (Irvingiaceae)

SANDRINE GALLOIS<sup>\*1</sup>, TINDE VAN ANDEL<sup>2,3,4</sup>, THOMAS HEGER<sup>4</sup>,  
BONAVENTURE SONKÉ<sup>5</sup>, AND AMANDA G. HENRY<sup>1</sup>

<sup>1</sup>Faculty of Archaeology, Leiden University, Leiden, the Netherlands

<sup>2</sup>Biosystematics Group, Wageningen University, Droevendaalsesteeg 1, 6708 PB, Wageningen, the Netherlands

<sup>3</sup>Naturalis Biodiversity Center, Leiden, the Netherlands

<sup>4</sup>Institute for Biology, Leiden University, Leiden, the Netherlands

<sup>5</sup>Plant Systematic and Ecology Laboratory, Department of Biology, Higher Teachers' Training College, University of Yaoundé I, P.O. Box 047, Yaoundé, Cameroon

\*Corresponding author; e-mail: galloissandrine.ethnoeco@gmail.com

---

## Comparing Apples and Pears: The Hidden Diversity of Central African Bush Mangoes (Irvingiaceae).

The fruits of Irvingiaceae trees, commonly known as “bush mangoes” or “mangues sauvages,” are crucial foods for Central African human populations, as well as local wildlife. Irvingiaceae oil-rich kernels play an important role in local diet, well-being, and livelihood. When collected for sale, they enter the international market of non-timber forest products (NTFPs), which represents a considerable source of income for central African countries. Despite the importance of bush mangoes, there is a general lack of precision in the literature on the exact species of Irvingiaceae present in local diets and NTFP markets. Few botanical studies include local names and uses of the different Irvingiaceae species, while ethnographical and social studies rarely corroborate their identifications by collecting vouchers. In this study, we combined ethnographic research and botanical collection to verify which Irvingiaceae species were consumed and collected for trade by the Baka, a group of forager-horticulturalists in southeastern Cameroon. We provide evidence of the floristic diversity hidden behind the term “bush mangoes”, as well as the knowledge and uses of Irvingiaceae fruits by the Baka. We discuss the importance of eight Irvingiaceae species for Baka livelihood as well as the potential threats regarding the future of these valuable trees.

## Confondre pommes et poires: La diversité cachée des mangues sauvages d'Afrique centrale (Irvingiaceae).

Les fruits des arbres de la famille des Irvingiaceae, communément appelés «mangues sauvages» ou «bush mangoes», sont des aliments cruciaux pour les populations humaines d'Afrique centrale, ainsi que pour la faune locale. Les graines oléagineuses des Irvingiaceae jouent un rôle important dans l'alimentation, le bien-être et les moyens de subsistance locaux. Quand elles sont collectées pour la vente, elles entrent sur le marché international des produits forestiers non ligneux (PFNL), représentant une source de revenus considérable pour les pays d'Afrique centrale. Cependant, malgré l'importance de ces mangues sauvages, la littérature témoigne d'un manque de précision sur les espèces d'Irvingiaceae

---

<sup>1</sup> Received 26 November 2019; accepted 26 May 2020; published online 8 July 2020

Received 25 November 2019; accepted 6 May 2020.

**Electronic supplementary material** The online version of this article (<https://doi.org/10.1007/s12231-020-09497-x>) contains supplementary material, which is available to authorized users.

présentes dans les régimes alimentaires locaux et les marchés des PFNL. Peu d'études botaniques incluent les noms locaux et les utilisations des différentes espèces d'Irvingiaceae, et les études ethnographiques et sociales corroborent rarement leurs identifications en collectant des échantillons botaniques. Dans cette étude, nous avons combiné recherche ethnographique et collections botaniques pour vérifier quelles espèces d'Irvingiaceae sont consommées et collectées pour le commerce par les Baka, un groupe de chasseurs-cueilleurs-horticulteurs du sud-est du Cameroun. Cette étude apporte des preuves de la diversité floristique cachée derrière le terme «mangues sauvages», ainsi que les savoirs et usages des Baka relatifs aux fruits d'Irvingiaceae. Ces résultats nous permettent de discuter de l'importance de huit espèces d'Irvingiaceae pour les Baka, ainsi que les menaces potentielles concernant l'avenir de ces précieux arbres.

**Key Words:** NTFP, Wild edible plants, Baka, Cameroon, *Irvingia*, *Desbordesia*, *Klainedoxa*, Mangues sauvages.

## Introduction

In the tropical rainforests of the Congo Basin, the fruits and kernels of Irvingiaceae trees, commonly known as “mangues sauvages” (bush mangoes), are crucial for the survival of both human and wildlife populations. The small Irvingiaceae family (three genera and ten species) is widely distributed in the lowland West and Central African forest, with the only exception being *Irvingia malayana* Oliv. ex A.W.Bennen, which occurs in Southeast Asia (Christenhusz and Byng 2016; Harris 1996). The fruits of the Irvingiaceae ripen in great quantities in a short period of time (mast fruiting). They have considerable carbohydrate content, 52% of dried matter for *I. gabonensis* (Aubry-Lecomte ex O'Rorke) Baill. (Hladik 1996), and fat content, 0.6% of dry weight for *I. gabonensis* and 0.5% for *Klainedoxa gabonensis* Pierre (Popovich et al. 1997). Therefore, Irvingiaceae kernels represent a significant nutritive intake for both people and wildlife (Dongmo et al. 2019; Fungo et al. 2016; Popovich et al. 1997). The consumption of fresh Irvingiaceae fruits and processed kernels has been documented extensively in Central Africa, specifically among forager groups who consume a number of different species. Bahuchet (1978) reported that the Aka, a forest-dwelling group in the Democratic Republic of Congo, used four wild *Irvingia* species: *I. gabonensis*, *I. robur* Mildbr., *I. wombulu* Vermoesen, and *I. grandifolia* (Engl.) Engl. These fruits are also one of the most important non-timber forest products (NTFP) that Central African foraging groups collect and trade for agricultural products with neighboring sedentary farmers (Ingram et al. 2017; Kitanishi 1994).

Since the mid-1990s, NTFPs, including bush mangoes, have been targeted by

international and national policies as key resources for alleviating poverty and promoting development (Ewane et al. 2009; Tchatat and Ndoye 2006). Today, there is a lively trade in Central African NTFPs within and between African nations, facilitated by the development of transport networks (Clark and Sunderland 2004). The interest in the fatty kernels of bush mangoes has spread from African forest areas to urban centers, even those in Europe and the United States, where they are sold mostly to the African migrant diaspora (Ingram and Schure 2010; Ingram et al. 2017; Ladipo 2000). Bush mangoes are the fourth most economically important NTFP of the Congo basin, after fish, firewood, and the leaves of *Gnetum* spp. (Ingram et al. 2017). In Cameroon, over 6387 tons of bush mango kernels valued at USD 8 million were harvested in 2010 (Ingram and Schure 2010). Bush mangoes are among the highest valued NTFPs (in the top five out of 129 plant-based products) as an economic good, but also for their use as food, raw material, socio-cultural marker, and for maintaining environmental integrity (Ingram and Schure 2010; Levang et al. 2015). However, in part because of their value, they are also increasingly threatened by illegal and unsustainable harvesting practices (Ingram et al. 2017), which place their long-term viability as a food source and NTFP at risk.

Despite the importance of these fruits, there is a general lack of knowledge about the exact species of Irvingiaceae that are eaten and/or sold. The literature on the commercialization and consumption of African NTFPs mostly identifies bush mangoes as either *I. gabonensis* only (Ayuk et al. 1999; Ngansop et al. 2019), or as *I. gabonensis* and *I. wombulu* (Awono et al. 2009; Ewane et al. 2009; Ingram et al. 2017). In general, *I. gabonensis* is said to be the sweet bush mango,

because of the sweet flavor of the edible fruit pulp, while *I. wombulu* is considered the bitter bush mango, of which only the kernels are eaten. However, some scholars have reported the use of other *Irvingia* species, referring to either *I. gabonensis* and *I. robur* (N'Guessan et al. 2015) or *I. gabonensis* and *I. excelsa* Mildbr. (Sato et al. 2012). Whereas botanists have identified six species of *Irvingia*, two species of *Klainedoxa*, and one species of *Desbordesia* in Africa (Harris 1996; Sonké and Couvreur 2014), and ethnographers have reported several Irvingiaceae species as used by local populations, like the Aka (Bahuchet 1978; Kitanishi 1994) and the Baka (Letouzey 1976), the ethnobotanical literature mostly reduces the bush mangoes to one or two species.

The ambiguity among the Irvingiaceae species used and traded has several sources. First, the kernels of the different *Irvingia* species are almost identical, making it impossible to differentiate between species when they are sold on the market (Brown et al. 2010; Ndoye et al. 1997). Second, there is significant variation in phenology, fruit morphology, color, and taste among *Irvingia* populations across West and Central Africa, which increases the difficulty of distinguishing sweet and edible fruits from bitter and inedible ones (Harris 1996; Vihotogbé et al. 2013). The revision of African Irvingiaceae species by Harris (1996) provides a clear overview of morphological and ethnobotanical characteristics of the different species, but unfortunately does not include local names. Most herbarium specimens also lack local names and uses. On the other hand, ethnographic studies on bush mango collection among local communities rarely provide any botanical evidence to support their species identification (e.g., Ingram et al. 2017; Ngansop et al. 2019; Yasuoka 2012; but see Kitanishi Kitanishi 1994 for a contrasting approach). Considering the importance of bush mangoes for local livelihoods and the increase of unsustainable and illegal harvesting of these species (Ingram et al. 2017), accurate data are needed on the botanical species hidden within the term “bush mangoes.” In this study, we clarify the “bush mango confusion” by providing botanical identifications of a variety of bush mangoes and related species of Irvingiaceae, based on fertile botanical specimens, with their local names used by the Baka, a group of forager-horticulturalists in southeastern Cameroon. We further describe how each species is used by the Baka, including harvesting and management practices, food processing, and trade for each taxon.

## Methodology

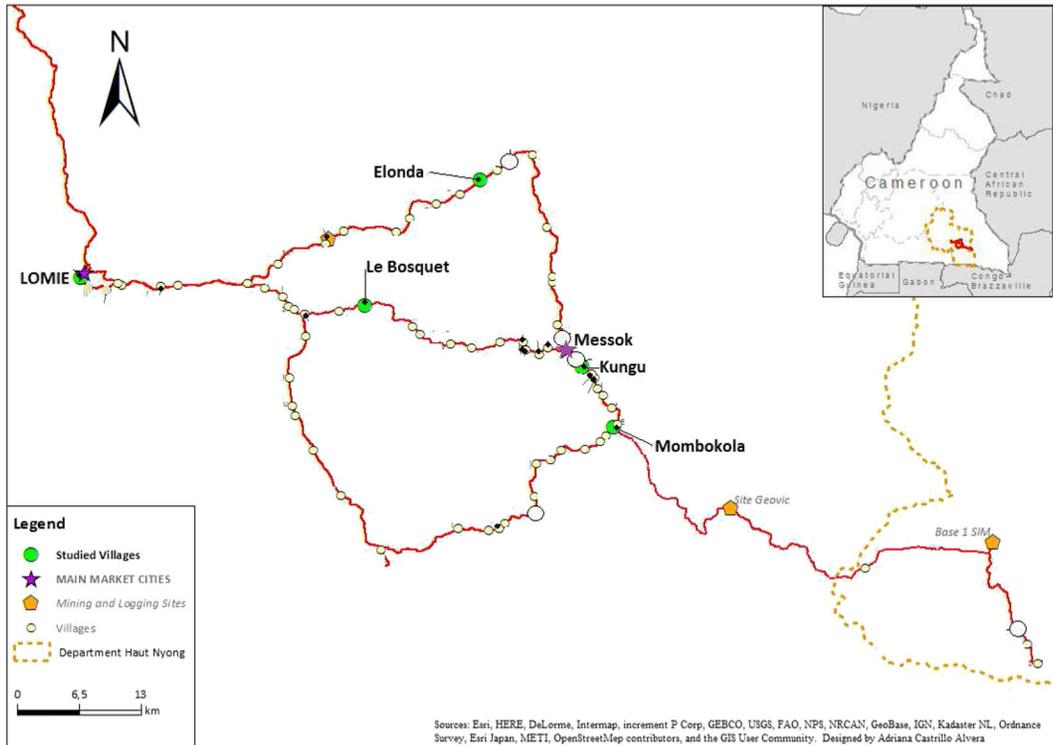
### STUDY SITES

This study was undertaken in the districts of Lomie and Messok, in the Haut-Nyong Division, East Region of Cameroon. The area is covered by a mixture of evergreen and moist semi-deciduous forest, at an altitude of 300–600 m. The climate of the region is tropical humid, with a major rainy season between late August and late November and a major dry season between late November and mid-March. The annual precipitation is about 1500 mm, and the average temperature is 25 °C (Leclerc 2012).

Along the logging roads, the primary forest is largely converted into secondary forest and shrubland, due to settlements, timber activities, cocoa farms, and small-scale agriculture. The forest where the Baka live is a mosaic of dense primary forest, secondary forest, cultivated and abandoned fields, all interspersed with trails.

Two main ethnic groups populate the area: the Nzimé, Bantu-speaking farmers, and the Ubangian-speaking Baka. Until roughly 50 years ago, the Baka were nomadic foragers, relying on hunting, fishing, gathering, and the exchange of NTFPs against agricultural products with their farming neighbors. Since the 1960s, the Baka have been facing several changes in their livelihood. Due to a government program of sedentarization, they have progressively left their forest camps and settled in villages along the logging roads. They have adopted agriculture and gained better access to schooling and basic health facilities. The Baka do not have any recognized territory, so the creation of national parks and conservation areas and the increasing exploitation of tropical hardwood continuously reduce their access to natural resources (Pyhälä 2012). Nowadays, their livelihood is mostly based on the combination of foraging activities, agricultural work in their own fields, and wage labor in their neighbors' fields or for logging companies.

We worked with four Baka communities (Elonda, Le Bosquet, Mombokola, and Kungu), which differed in size, environmental setting, and degree of market integration (Fig. 1). Le Bosquet (pop. 800) is the largest community, with a missionary center, school, church and health center, several bars, and small shops owned by Nzimé and northern Cameroonians. Elonda and Mombokola are quite similar, with 300 to 400 inhabitants, a



**Fig. 1.** Map of the study area

school, and a small shop. People from the community Kungu (pop. 200) live primarily in their forest camp, 1.5 h walking from the logging road, surrounded by agricultural fields, secondary and selectively logged primary forest, without any shop or school.

#### DATA COLLECTION

For this project, we traveled to the Baka communities on three occasions. In the two first field seasons (February–March and October–November 2018), the first author collected quantitative and qualitative data regarding wild plant use by means of interviews with Baka adults and children (see [Electronic Supplementary Material \[ESM\]](#), Appendix 1). During the third season (April–May 2019, the minor rainy season), the three first authors (an eco-anthropologist, an ethnobotanist, and an MSc student in plant science) collected botanical vouchers of wild food plants that the Baka reported eating. All interviews were conducted in the Baka language with the help of two local research-

assistant/interpreters: a Baka man and a Nzimé man from the area. Both spoke Baka and were trained to read and write Baka using International Phonetic Alphabet norms, thanks to their experience as teachers in a private school where all instruction was given in Baka (Frere des Ecoles Chrétiennes). They were also trained in anthropological and ethnobotanical research methods during their involvement in a previous research project led by the first author. Additionally, the first author is able to speak, read, and write Baka language in IPA.

Before collecting the data, we presented our research, its objectives and insights, and obtained Free Prior and Informed Consent in all the villages and from every individual participating in this study. We also asked for parental consent before working with children. This study adheres to the Code of Ethics of the International Society of Ethnobiology and received the approval of the ethics committee of Leipzig University (196–16/ek), and the Ethical Committee from the Ministry of Health of Cameroon (n°2018/06/1049/CE/CNERSH/

SP). We obtained a plant collection permit from the Cameroonian Ministry of Health and a specimen export permit from the National Herbarium of Cameroon in Yaoundé (YA).

The botanical vouchers and associated information were collected during 14 single-day trips in the forest surrounding the villages using the “walk-in-the-woods” method (Phillips and Gentry 1993) with 16 informants (nine men and seven women, aged 25 to ca. 70 years). Local guides were chosen by the representatives of the communities, who selected the most knowledgeable members including both sexes and all age groups. The collection sites were chosen by the informants, upon being asked to show us the wild edible plants (WEP) they knew. Specimens were collected along logging roads, forest trails, near agricultural fields, in hunting and gathering grounds, and in both secondary and selectively-logged primary forests (recognizable by recently felled tree trunks). For every specimen collected, local informants were asked: a) what were the local names, uses, and preparation methods; b) whether the tree was commercially logged; c) whether seeds or fruits were sold; d) whether the species was planted or spared from weeding; and e) when they had last consumed this species. The spelling of all Baka names mentioned during the walk-in-the-wood expeditions and interviews was verified using Baka-French dictionaries (Brisson 2010).

Three voucher specimens were made per collection using standard botanical methods. One specimen was deposited at the National Herbarium of Cameroon in Yaoundé (YA), one was used in the field to verify and further discuss local names and uses with the Baka, and the third was deposited at Naturalis Biodiversity Center (L) in Leiden, the Netherlands, where the final identifications took place. Plants were identified using the most recent revision of African Irvingiaceae (Harris 1996), general botanical literature on the West and Central African flora (Hawthorne and Jongkind 2006), and herbarium specimens of Irvingiaceae species at Leiden, most of which were revised in 1993–1994 by David J. Harris of the Royal Botanic Garden Edinburgh. All the pictures presented here were taken by the first author.

General knowledge about the different bush mango species was collected from focus group discussions, semi-structured surveys, and participant observation during previous fieldwork made by

the first author between 2012 and 2014 (ESM, Appendix 1). Additional data were gathered during the botanical expedition in April 2019, and two focus group meetings (ca. 80 participants) in May 2019, during which we asked the Baka participants to verify local names, knowledge, and uses, and to provide extra information about the different species. We also assessed the importance of bush mangoes in Baka diets and livelihood by a series of interviews conducted during the first two field seasons in 2018 (Gallois et al. 2020).

Data on bush mango consumption were retrieved from 24-h recall surveys on dietary diversity. During these interviews, informants were asked to report all the food and drinks they had consumed in the previous 24 h, including small snacks. A total of 223 interviews were conducted among 160 individuals (96 women, 64 men) in the four villages (33 in Le Bosquet, 44 in Elonda, 45 in Kungu, and 38 in Mombokola); 63 individuals were interviewed twice and 97 only once. To assess how bush mangoes contributed to Baka livelihood, we retrieved data from 14-day income recall surveys in which informants were asked to report all the income they had received from wage labor and items sold or bartered during the last 2 weeks. A total of 221 recalls took place among 150 individuals (94 women, 56 men) in the four villages: Le Bosquet (34), Elonda (38), Kungu (39), and Mombokola (39); 71 individuals were interviewed twice and 79 only once (Gallois et al. 2020).

#### DATA ANALYSIS

All data on knowledge, practices, and uses of Irvingiaceae collected by the different methods were merged into a single spreadsheet. From the dietary recalls, we calculated the frequency of every wild plant reported as consumed in different seasons. From the income survey, we first calculated the overall income received from wage labor and sales over the four communities and the two field seasons (major dry and rainy seasons). Then, we grouped the income from sales in different categories: a) modern items; b) game, fish, and insects; c) wild plants; d) other wild edibles; e) handicrafts; and f) crops. We calculated the total amount of income received for each category over all interviews. We then specifically calculated the income generated by the sale of each wild plant species reported.

## Results

### BOTANICAL IDENTIFICATION OF IRVINGIACEAE SPECIES

In total, we collected botanical vouchers of eight different Irvingiaceae species used by the Baka: five species of *Irvingia*, referred to under the collective term “mangues sauvages,” two species of *Klainedoxa*, and one species of *Desbordesia* (Table 1). We were therefore able to collect representatives of all of the Irvingiaceae species present in Cameroon, except *I. smithii* Hook. f., which is very rare in Cameroon and only known from one location along the border with Congo Brazzaville (Harris 1996; Kenfack et al. 2007).

### LOCAL CLASSIFICATION OF BUSH MANGOES

The naming conventions for the bush mangoes among the Baka includes both species-specific identifiers and more general group names (Fig. 2). Confusingly, the name used for one particular species may also apply to a group. In Baka language, **payo** refers to the specific species *I. excelsa*, but also to a group of similar-looking bush mangoes that includes **pekè** (*I. gabonensis*), **gangendi** (*I. wombulu*), and **kòmbèlè** (*I. robur*). Typically, **sóðlià**, *I. grandifolia* is not considered to be **payo**, probably because the fruits are much smaller (Fig. 3).

The two *Klainedoxa* species are grouped under the general term, **bòkòkò**, which is also used specifically for the very commonly occurring *K. gabonensis* (Fig. 4). Because of its smaller fruits, the less common **bondulu** (*K. trillesii*) is considered to be the “younger brother” of *K. gabonensis*.

Finally, **ntuo** (*Desbordesia insignis*) is considered to be a separate entity.

The Baka distinguish the different species based on their taste, fruit size, the shape of their leaves, and the habit of the trees. For instance, *I. robur* (Fig. 5) is said to have larger fruits and seeds than *I. gabonensis*, whereas *I. excelsa* is said to have stronger kernels than *I. gabonensis*, which makes their processing more difficult.

Due to its bright pink stipules and young leaves, *D. insignis* can be distinguished from a large distance. The pink crowns of these trees are clearly visible in Baka villages along logging roads (Fig. 6).

### HABITAT AND DOMESTICATION

All species of Irvingiaceae occur naturally in primary forest, but when the Baka cut forest for agricultural fields, they spare these trees because they provide them with valuable fruits. It is therefore common to find Irvingiaceae trees as emergent in secondary forests, in shrubland around villages, and along logging roads. However, the large majority of Irvingiaceae fruits and kernels are gathered in the forest, either secondary or (selectively logged) primary forest. In contrast to Irvingiaceae trees in the forest, of which the fruits are available for everyone, trees that grow on or near agricultural fields are seen as property of the owner of the field, who may prohibit fruit collection by other Baka. According to our informants, only *Desbordesia insignis* was sometimes planted from seed, while all other species were considered as wild. However, during our forest walks, some informants collected Irvingiaceae seedlings to plant closer to their home, which suggests that other bush mango species may be deliberately planted as well.

TABLE 1. SCIENTIFIC AND LOCAL NAMES OF THE IRVINGIACEAE SPECIES COLLECTED

Voucher Number*	Baka Name	Scientific Name	Consumed Part
WTH 44	payo	<i>Irvingia excelsa</i> Mildbr.	kernels (roasted and pounded, or raw)
WTH 16	pekè	<i>Irvingia gabonensis</i> (Aubry-Lecomte ex O'Rorke) Baill.	fresh fruits, kernels (roasted and pounded, or raw)
WTH 97	gangendi	<i>Irvingia wombulu</i> Vermeesen	kernels (roasted and pounded, or raw)
WTH 47	kòmbèlè	<i>Irvingia robur</i> Mildbr.	kernels (roasted and pounded, or raw)
WTH 36	<b>sóðlià</b>	<i>Irvingia grandifolia</i> (Engl.) Engl.	kernels (roasted and pounded, or raw)
WTH 56	ntuo	<i>Desbordesia insignis</i> Pierre.	kernels (roasted and pounded)
WTH 68	bondulu	<i>Klainedoxa trillesii</i> Pierre ex Tiegh.	kernels (roasted, boiled, or raw)
WTH 17	<b>bòkòkò</b>	<i>Klainedoxa gabonensis</i> Pierre	kernels (raw)

\*The acronym WTH refers to co-author Willem Thomas Heger

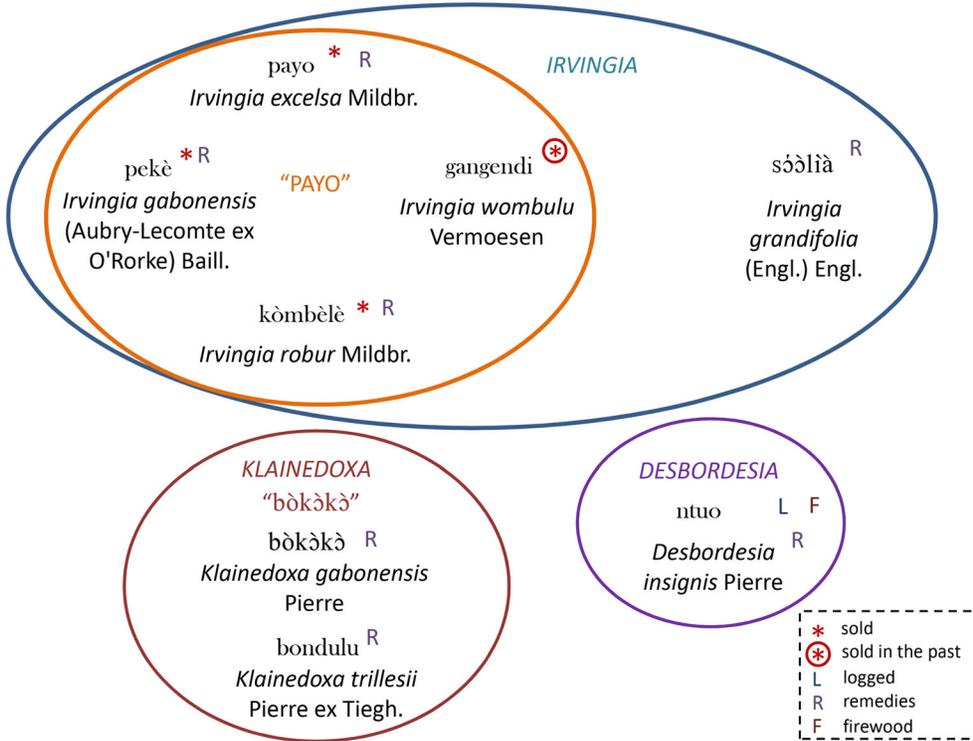


Fig. 2. Baka classification of the eight Irvingiaceae species with their local names, general Baka terms, and uses other than food

SEASONALITY

The Baka differentiate four seasons: the major dry, the minor rainy, the minor dry, and the major rainy seasons. The time when bush mangoes fruit is a key period in their yearly calendar. It is often used as a temporal marker when referring to past events **sòkòpeké**, the “bush mango season,” specifically refers to the fruiting period of *I. excelsa* (**payo**) and *I. gabonensis* (**peké**) in June–July, as the other Irvingiaceae species ripen in other times of the year (Fig. 7).

The importance of the bush mango fruiting season is reflected in the mobility patterns of the Baka: between June and August, many families go on collecting trips into the forest to gather *Irvingia* fruits. From children to elders, all family members are involved in gathering the fruits and seeds. In this period, families may spend several weeks to months in the forest, staying at a forest camp or shifting between several camps depending on the availability of *Irvingia* trees in the surroundings. While all Irvingiaceae have massive fruiting periods, *I. excelsa*

and *I. gabonensis* were the species most commonly eaten and sold in the four study sites, and said to be the most abundant in the forest.

LOCAL PREPARATION AND USES OF IRVINGIACEAE

In general, all Irvingiaceae fruits are collected from the ground. Only the fruit pulp of *I. gabonensis* is consumed raw; the fruits of the other species are so bitter that only the kernels are eaten. The Baka open the fruits with a machete and take out the fatty kernels, either at the place the fruits were collected or back in the camp (Fig. 8). The kernels of all eight Irvingiaceae species are eaten raw during collecting, especially by children. The adults also collect the kernels in wicker rattan baskets lined with Marantaceae leaves. This process of fruit collection and removal of the kernels takes a considerable amount of effort. The Baka consider the Irvingiaceae to be one of the most difficult wild foods to gather, because of the time needed to extract the kernels. They have to knock the hard seeds several times with a machete before they split

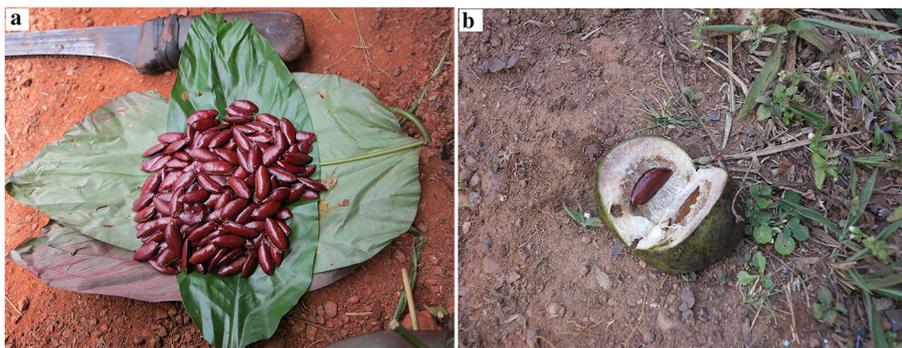


**Fig. 3.** Dried fruits of the five species of Irvingiaceae collected in southeast Cameroon, with their Baka names. Note the significant size difference between *I. grandifolia* and the four other species, which are commonly referred to under the collective noun **payo**. Most of these shells are empty; only for *I. wombala* is the inner kernel also shown on the bottom row

and the kernels can be taken out. Piles of decaying opened fruits are frequently seen along forest paths.

Kernels from all Irvingiaceae are also roasted. They may be first dried in the sun for several days or on a grid above the fire. They may also be roasted on an aluminum sheet or a pot cover, which allows the Baka to use the kernels shortly after gathering. The

*Klainedoxa* species are more frequently consumed raw or roasted, but rarely included in more elaborate dishes. In contrast, the *Irvingia* species are often processed further. Once roasted, they are pounded in a wooden mortar or ground into a powder on a wooden board with a dried **buku** fruit (*Strychnos aculeata* Soler.). The powder can then be mixed with water and salt and boiled into a sauce, which



**Fig. 4.** Fresh kernels and opened fruit of *Klainedoxa gabonensis*



Fig. 5. Open fruit with fresh kernel of *Irvingia robur*

is eaten with starchy food such as cooked cassava, plantain, or yams. This powder is also added to more elaborate dishes, such as stews with green leaves from wild plants (e.g., *Gnetum* spp.) or cultivated vegetables (e.g., cassava leaves), meat, fish, or

combinations of these. The kernels are appreciated for their flavor and fat.

The Baka also prepare a paste or cake from *Irvingia* kernels for longer storage. Only the kernels from *I. excelsa* and *I. gabonensis* were reported to be used in this manner. After the Baka collect great quantities of kernels, they dry them for 2 or 3 weeks and then store them on a rack above the fire. They then roast the kernels and pound them in a mortar, which produces an oily dough from which the oil often separates. They line a pot with banana leaves, pour the dough and separated oil on top, and mix the two together. The resulting cake is allowed to dry in the sun for 2 days, so that the oil is re-absorbed into the dough. This cake, known as **mupekè**, can be kept for 1 or 2 years without spoiling. When it is needed, they scrape off a small portion of the cake and use the resulting powder in dishes (Fig. 9).

Irvingiaceae trees also have other uses, such as firewood (*Desbordesia insignis*) or medicine. *I. robur* and *I. excelsa* were reported to be used for treating stomach pain, and *Klainedoxa trillesii* was used to treat diarrhea. *I. gabonensis* was reported to cure malaria. For all of them, the medicine was prepared similarly: the bark was scraped, the powder added to water and drunk. The bark from *Klainedoxa gabonensis* and *I. grandifolia* was used in rituals before hunting expeditions, in order to bring luck to the hunter. The exact means by which the barks are used in these rituals were not shared by our informants.

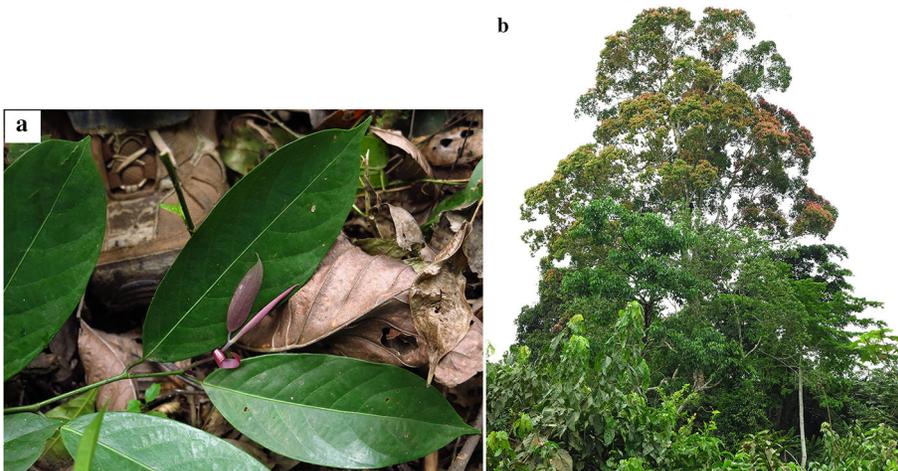


Fig. 6. a Pink stipule and young leaf of *Desbordesia insignis*; b crown of *D. insignis*

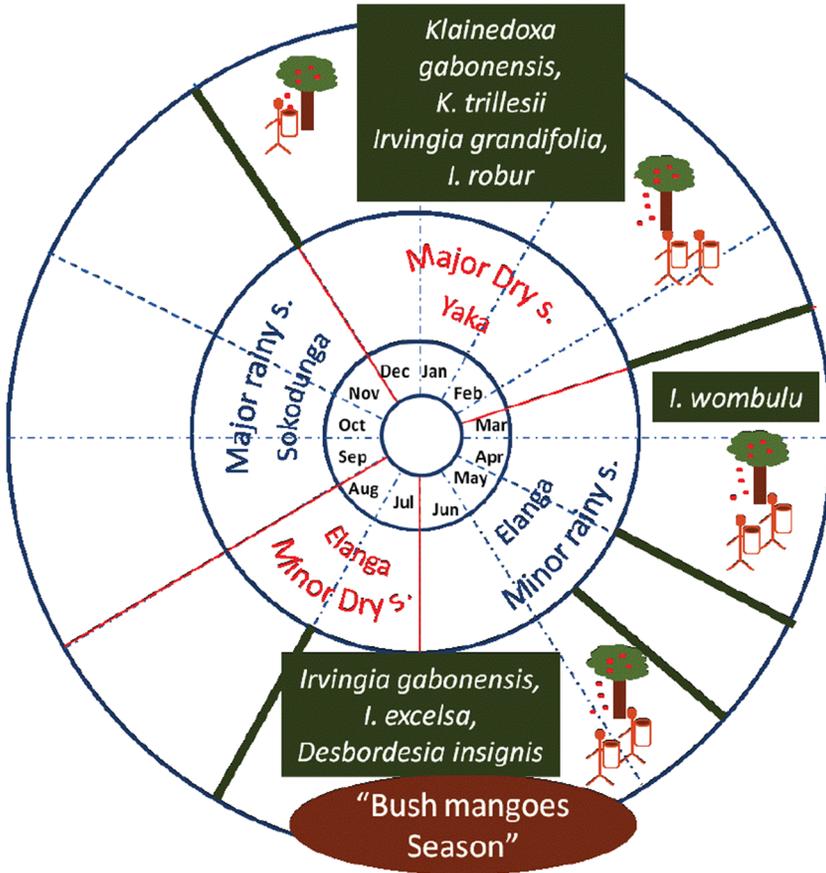


Fig. 7. Fruiting seasons of Irvingiaceae species in southeastern Cameroon according to our Baka informants



Fig. 8. Opening *Irvingia* fruits with a machete to extract the kernels



**Fig. 9.** Production of an *Irvingia* kernel cake **mupekè**. From left to right: **a** roasting the kernels, **b** powdered kernels, **c** dough in a pot lined with banana leaves, and **d** dried cake

#### IMPORTANCE OF BUSH MANGO SPECIES IN DIETARY RECALLS

Although eight different Irvingiaceae species are collected for their fatty kernels, only two local names were reported in the dietary recalls in the four villages: **pekè** and **payo**, of which the latter was most frequently reported as consumed in the past 24 h (Table 2). However, during the interviews, we did not ask whether the informant was referring to real **payo** (*I. excelsa*) or one of the other three other species known under this collective name (*I. gabonensis*, *I. wombulu*, and *I. robur*), as we did not understand at that time that the term was sometimes used for all four of these species. Regardless, **pekè** (*I. gabonensis*) is the most preferred Irvingiaceae species. When asking 100 Baka informants about their preferred wild edible plants, *I. gabonensis* was the only Irvingiaceae species that appeared on the list, and was ranked seventh of the most favored wild food plants (Gallois et al. 2020).

None of the *Klainedoxa* species was mentioned in these recalls, but during the trips in which we collected voucher specimens, we frequently encountered areas where large amounts of *Klainedoxa* fruits

had been processed. *Desbordesia insignis* also was absent from the dietary recalls, but whether this was because our fieldwork seasons did not coincide with its fruiting season or because its kernels were eaten only as a forest snack remains unclear.

#### COMMERCIAL HARVESTING

Merchants from West and North Cameroon regularly come to Baka villages by car or motorcycle to buy *Irvingia* kernels. During the 14 days income surveys, only **payo** (*Irvingia* spp.) and **pekè** (*I. gabonensis*) were reported as being sold to middlemen, either to foreigners from other parts of Cameroon or to Nzimè, who also buy the kernels for their own consumption. During focus group discussions, the Baka specified that *I. excelsa* and *I. gabonensis* were the most commonly sold, while *I. wombulu* and *I. robur* were sold less frequently. The price paid for the kernels varied among villages, individual collectors, and merchants. In Elonda, a two-liter container of dried kernels (the equivalent of 1 kg) was sold in 2019 for USD 1–5 (600–3000 XFA), while a 2 kg cake of *I. gabonensis* kernels for about USD 6. Overall, in the 14-day income recalls,

TABLE 2. WILD PLANTS REPORTED AS CONSUMED IN THE PAST 24 H, IN ORDER OF FREQUENCY

Baka name	Scientific name	Number of citations	Frequency ( $n = 255$ )
kòkò	<i>Gnetum cf. africanum</i> Welw.	134	59.6%
payo	<i>Irvingia excelsa</i> Mildbr., <i>Irvingia</i> spp.	42	18.7%
màbè	<i>Baillonella toxisperma</i> Pierre	18	8.0%
pekè	<i>Irvingia gabonensis</i> (Aubry-Lecomte ex O'Rorke) Baill.	13	5.8%
kanà	<i>Panda oleosa</i> Pierre	11	4.9%
sapà na bele	<i>Dioscorea praehensilis</i> Benth.	9	4.0%
kèkè	<i>Dioscorea burkilliana</i> J. Miège	7	3.1%
ngimbà	<i>Afrostyrax lepidophyllus</i> Mildbr.	6	2.7%
ba	<i>Dioscorea cf. praehensilis</i> Benth	5	2.2%
súmba	<i>Hillieria latifolia</i> (Lam.) H. Walter	2	0.9%

Data from 255 dietary recalls among 160 individuals in four villages

the total revenue earned reported for all the 221 interviewed participants from both sale and wage labor was about USD 983, of which about two-thirds was from selling NTFPs (Fig. 10 and Table 3). The sale of *Irvingia* kernels represented the highest share (36%) of the income provided by wild-collected plants. Of these, most (34%) were reported as **payo**, which might refer to four different species, including *I. excelsa*. Overall, the sale of *Irvingia* kernels provided about 9.5% of the total

income earned by the Baka during these 14 recalled days.

Recently, commercial timber companies have started to log *Desbordesia insignis* trees. The other Irvingiaceae are not yet felled for the hardwood trade in this area. However, some Baka informants reported that a destructive form of bush mango gathering was taking place during the peak fruiting season of *I. gabonensis*. Baka harvesters searching for quick cash entered the protected Dja faunal reserve,

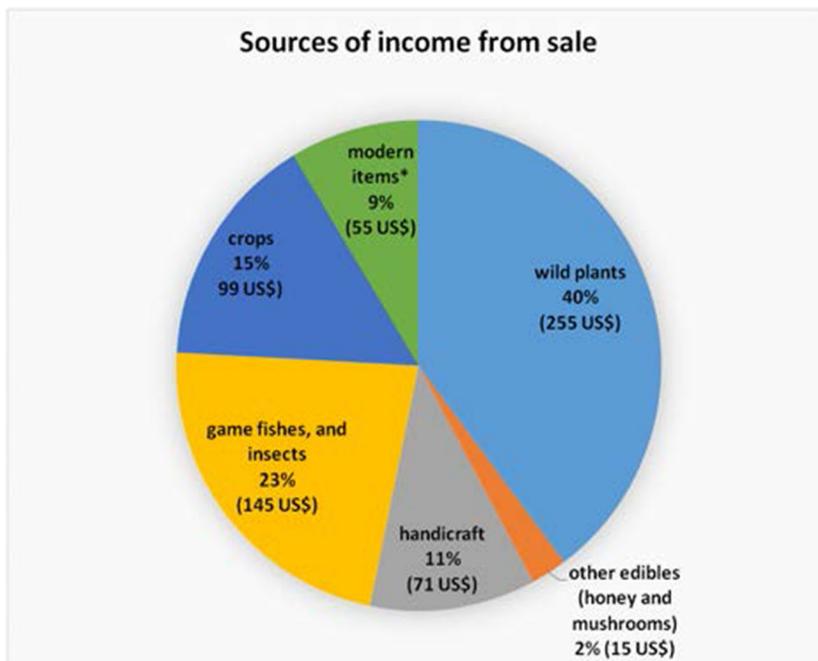


Fig. 10. Reported sources of income through selling local goods (223 interviews over 156 individuals). \*Marketable products such as alcohol and pens, first bought by Baka in local shops and then sold afterwards to their peers

TABLE 3. TOTAL INCOME PER 14 DAYS FROM THE SALE OF WILD PLANTS BY 221 PARTICIPANTS

Baka name	Scientific name	Income [USD]	No. recalls
pekè	<i>Irvingia gabonensis</i>	88	7
kòkò	<i>Gnetum cf. africanum</i>	69	44
tóndo	<i>Aframomum</i> spp. (including <i>A. cf. longipetiolatum</i> Koechlin., <i>A. sceptrum</i> (Oliv. & D. Hanb.) K. Schum., <i>A. subsericum</i> (Oliv. & D. Hanb.) K. Schum., <i>A. danielli</i> (Hook.f.) K. Schum.)	52	7
ngìmbà	<i>Afrostyrax lepidophyllus</i>	22	3
mbalaka	<i>Pentaclethra macrophylla</i> Benth.	16	5
màbè	<i>Baillonella toxisperma</i>	3	2
payo	<i>Irvingia</i> spp.	4	1
Total		255	68

a UNESCO World Heritage Site located about 30 km from our study area, and cut several trees to be the first to collect the fruits and sell the kernels. This has led to conflicts between Baka and park rangers.

## Discussion

### BUSH MANGO DIVERSITY

Our study demonstrates the hidden diversity of Irvingiaceae species behind the term “bush mango.” Through direct observation, botanical vouchers, and discussions with local informants, we reveal that in southeastern Cameroon, a bush mango can belong to four different species from the Irvingiaceae family. In our study site, francophone area of Cameroon, the term **payo** is translated into French as “mango” or “mangue sauvage” (“bush mango”) and therefore may refer to different *Irvingia* species. Furthermore, there are four different species of Irvingiaceae whose fruits taste bitter (*I. excelsa*, *I. wombulu*, *I. robur*, *I. grandifolia*), instead of only *I. wombulu* as commonly reported in the literature (Ewane et al. 2009; Ingram et al. 2017; Tchoundjeu et al. 2005). Consistent with genetic research (Lowe et al. 2000), *I. gabonensis* and *I. wombulu* are easily distinguished by local people. In contrast to Vihotogbé et al. (2019), we found both *I. gabonensis* and *I. wombulu* in our study site, implying that these species overlap in this area.

These insights allow us to discuss the limitations of relying only on local names when conducting ethnobotanical research. Two main drivers of bias have to be considered: folk classification and the dynamic nature of language. In the case of Irvingiaceae, local Baka terms might lead to

confusion: **payo** can refer to *I. excelsa* and to a group of four *Irvingia* species. Unless the informant is further probed, the other taxa (*I. robur*, *I. wombulu*, and *I. gabonensis*) are likely to be ignored or at best underrepresented in studies relying on self-reported surveys. Using generic categorization for groups of species is a common phenomenon in all languages (Berlin 1992). It is thus highly possible that previous studies, based on reports of local names, which have shown the predominance in other settings of *I. gabonensis* as THE bush mango, may have been affected by this linguistic bias. Moreover, relying on local names only is also problematic due to the intrinsic dynamic nature of language. Most, but not all Baka names we collected matched with previous botanical identifications of specimens collected in the same area by Letouzey (1976). For Irvingiaceae, however, *I. wombulu* was reported as **móbolù**, and *Desbordesia* as **melea**. These different terms might be due to geographical or temporal variability of terminology, or both. It is common that plant names evolve through time and through inter-cultural exchanges, as for instance the adoption of some Bantu vocabulary in Baka language and vice versa (Gallois et al. 2017; Letouzey 1976). Because of the difficulties in identifying the different *Irvingia* species and linguistic variation, any study working on these ethnobotanical resources should consider these limitations in their methods and analysis; otherwise they maybe comparing apples and pears.

### IMPORTANCE OF IRVINGIACEAE TREES FOR BAKA LIVELIHOOD

Our work highlights the importance of the eight Irvingiaceae species for Baka diet, income, and

culture. Our quantitative results under-represented the importance of Irvingiaceae for the Baka due to the fact that our data were collected out of the main fruiting season and thus did not catch the peak in consumption and commercialization. However, we know from our ethnographic data that Irvingiaceae kernels are consumed on an almost daily basis during the weeks in which the fruits ripen, the highest consumption being in July and August. During this fruiting season, the consumption of *Irvingia* spp. may provide the Baka with more than 50% of their daily caloric intake (Yasuoka 2012). Moreover, our survey data were collected primarily in villages along the logging roads. The Baka usually consume more wild plants when staying in forest camps, like other foraging groups such as the Mbuti (Ichikawa 1996). Despite the probable bias, our data nevertheless indicate a strong reliance on these fruits. Our study is the first to show that the Baka regularly sell four *Irvingia* species, while previous studies identified only *I. gabonensis* and *I. wombulu* as the commercial bush mangos (Ainge and Brown 2004; Ayuk et al. 1999). Given the economic value of bush mangoes, its increasing commercialization (Ingram 2014), and reports of logging companies and Baka harvesters felling *Irvingia* trees in protected areas (Ingram et al. 2017), the identification of commercialized species is essential for the assessment of harvest sustainability and the design of management and conservation plans. As the kernels alone are difficult to tell apart, our insights support the importance of genetic research (DNA fingerprinting) to detect the proportion of the individual species on the international market.

Irvingiaceae fruits play a key role in Baka well-being and culture. The period just preceding the main *Irvingia* fruiting period is known for food scarcity, particularly a shortage of bushmeat. This period of “meat hunger,” a common feature among foragers in Central Africa (Pagezy 1982), induces feelings of stress, tiredness, or depression (Dounias and Ichikawa 2017). When the *Irvingia* fruiting season finally starts, the Baka even more keenly appreciate the taste and fat contribution to their daily meals, and the relative abundance of food (Joiris 1996). Although very seasonal, the sale of Irvingiaceae fruits is a major source of income for the Baka, and is the only major transaction in which they directly receive money. The sale of the other two main goods, cacao and timber, provides money to the Nzimé, who then share the proceeds with the Baka. *Irvingia* kernels are thus a key product for Baka empowerment in a context of general

marginalization. *Irvingia* fruits also play an important role in Baka culture by being the main drivers for extended forest trips. Since the hunting of large mammals (elephants, gorillas, chimpanzees) is now prohibited by law, the collection of bush mangoes is nowadays the main reason why the Baka stay in forest camps for long periods of time (Gallois 2017). Far from the confrontations on wage labor with Nzimé farmers, the bars, and associated alcohol problems, time spent in the forest is crucial for the transmission of ecological knowledge, as children directly interact with their environment and can benefit from the storytelling taking place at night in the forest camps.

#### HARVESTING IRVINGIACEAE IN A CHANGING ENVIRONMENT

The nutritional and commercial potential of *Irvingia* kernels has been the focus of several development initiatives. In 1996, *I. gabonensis* was identified as a priority species for domestication (Atangana et al. 2001), and several programs were launched in southwest and central Cameroon (Asaah et al. 2003). In our study site, the bulk of the Irvingiaceae kernels were collected from the wild, although several informants planted *Irvingia* seedlings close to their house or field. Access to these forest resources, however, is challenged by social and ecological pressure threatening the Irvingiaceae population: unsustainable harvesting and the disappearance of wildlife. The increasing demand for *Irvingia* kernels in urban centers in and outside Africa leads to unsustainable gathering methods such as felling trees (Ingram et al. 2017), which was also reported by the Baka. The money from selling the kernels may be perceived as more profitable for the Baka than home consumption, so future market pressure may drive the Baka to over-exploit their forest resources while simultaneously impoverishing their diet. The future of Irvingiaceae is also threatened by the decrease of wildlife in this area, as the trees depend on large mammals, especially elephants, for the dispersal of their seeds (Beaune et al. 2013; Campos-Arceiz and Blake 2011). Some species of Irvingiaceae (*I. grandifolia* and *K. gabonensis*) take longer to germinate when they do not pass through an elephant gut (Beaune 2015; Beaune et al. 2013). Even though other dispersers assume the role of the elephants, they cover shorter distances, which limits genetic exchanges between Irvingiaceae populations and may cause an increase of mortality due to density issues

(Beaune et al. 2013). Because of their mobility, the Baka might take over the role of Irvingiaceae seed dispersers, but obviously to a much lesser extent and not sufficient to maintain these populations. Therefore, the conservation of Irvingiaceae trees, being both ecological and cultural keystone species (Beaune et al. 2013), is essential, considering the cascade effect implied by their potential disappearance.

### Acknowledgments

*This research has received funding from the European Research Council under the European Union's Horizon 2020 research and innovation program, grant agreement number STG-677576 (HARVEST). The botanical fieldwork was funded by Naturalis Biodiversity Center, the Treub Maatschappij and the Alberta Mennega Foundation. We would like to thank our Cameroonian colleagues, especially Appolinaire Ambassa, Ernest Isidore Simpoh, and Alain Hyppolite Fezeu, for their help with the fieldwork. Finally, our greatest gratitude goes to all Baka children, women, and men with whom we have lived and worked. Thank you for your trust, hospitality, and generous hearts.*

**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

### References

- Ainge, L. and N. Brown. 2004. Bush mango (*Irvingia gabonensis* and *I. wombulu*). In: The key non-timber forest products of Central Africa: State of the knowledge. Technical paper n°122, eds. L.E. Clarck and T.C.H. Sunderland, 15–36. Washington DC: US Agency for International Development (USAID).
- Asaah, E.K., Z. Tchoundjeu, and A.R. Atangana. 2003. Cultivation and conservation status of *Irvingia wombulu* in humid lowland forest of Cameroon. *Journal of Food Agriculture and Environment* 1:251–56.
- Atangana, A.R., V. Ukafor, P. Anegbeh, E. Asaah, Z. Tchoundjeu, J. Fondoun, and R.R.B. Leakey. 2001. Domestication of *Irvingia gabonensis*: 2. The selection of multiple traits for potential cultivars from Cameroon and Nigeria. *Agroforestry Systems* 55(3): 221–30.
- Awono, A., A. Djouguep, L. Zapfack, and O. Ndoye. 2009. The potential of *Irvingia gabonensis*: Can it contribute to the improvement of the livelihoods of producers in southern Cameroon? *International Journal of Social Forestry* 2(1):67–85.
- Ayuk, E.T., B. Duguma, S. Franzel, J. Kengue, M. Mollet, T. Tiki-Manga, and P. Zenkeng. 1999. Uses, management and economic potential of *Garcinia kola* and *Ricinodendron heudelotii* in the humid lowlands of Cameroon. *Journal of Tropical Forest Science* 11(4):746–61.
- Bahuchet, S. 1978. La cueillette chez les pygmées Aka, chasseurs-cueilleurs de la foret centrafricaine. *Societe d'Ethnozoologie et d'Ethnobotanique Bulletin de Liaison* 4(1):21–25. <https://hal.archives-ouvertes.fr/hal-00383254>.
- Beaune, D. 2015. What would happen to the trees and lianas if apes disappeared? *Oryx* 49(3):442–46. <https://doi.org/10.1017/S0030605314000878>.
- Beaune, D., B. Fruth, L. Bollache, G. Hohmann, and F. Bretagnolle. 2013. Doom of the elephant-dependent trees in a Congo tropical forest. *Forest Ecology and Management* 295: 109–17.
- Berlin, B. 1992. *Ethnobiological classification: Principles of categorization of plants and animals in traditional societies*. Princeton: Princeton University Press.
- Brisson, R. 2010. *Petit dictionnaire Baka-Français. Sud Cameroun*. Paris: L'Harmattan.
- Brown, H., C. Peach, and J.P. Lassoie. 2010. The interaction between market forces and management systems: A case study of non-wood forest products in the humid forest zone of Cameroon. *International Forestry Review* 12(1):13–26.
- Campos-Arceiz, A. and S. Blake. 2011. Megagardeners of the forest—The role of

- elephants in seed dispersal. *Acta Oecologica* 37(6):542–53. <https://doi.org/10.1016/j.actao.2011.01.014>.
- Christenhusz, M.J. and J.W. Byng. 2016. The number of known plants species in the world and its annual increase. *Phytotaxa* 261(3):201–17. <https://doi.org/10.11646/phytotaxa.261.3.1>.
- Clark, L.E. and T.C.H. Sunderland. 2004. The key non-timber forest products of Central Africa: State of the knowledge. Technical paper n°122. Washington DC: US Agency for International Development (USAID).
- Dongmo, L., R. Tédonzong, J. Willie, N. Tagg, M.N. Tchamba, T. Evaristus, A. Myriane, P. Keuko, and C. A. Petre. 2019. The distribution of plant consumption traits across habitat types and the patterns of fruit availability suggest a mechanism of coexistence of two sympatric frugivorous mammals. *Ecology and Evolution* 9(8): 4473–94.
- Dounias, E. and M. Ichikawa. 2017. Seasonal bushmeat hunger in the Congo Basin. *EcoHealth* 14(3):575–90. <https://doi.org/10.1007/s10393-017-1252-y>.
- Ewane, M.E., V. Ingram, and A. Awono. 2009. Baseline study on *Irvingia* spp. in the South West and East regions of Cameroon. Unpublished report CIFOR, Yaoundé, Cameroun.
- Fungo, R., J. Muyonga, M. Kabahenda, A. Kaaya, C.A. Okia, P. Donn, T. Mathurin, O. Tchingsabe, J.C. Tiegehungo, J. Loo, and L. Snook. 2016. Contribution of forest foods to dietary intake and their association with household food insecurity: A cross-sectional study in women from rural Cameroon. *Public Health Nutrition* 19(17):3185–96.
- Gallois, S. 2017. Growing up in a changing world. A case study among Baka children (southeastern Cameroon). *AnthropoChildren* (7): 1–20. <https://popups.uliege.be/443/2034-8517/index.php?id=2755>.
- Gallois, S., R. Duda, and V. Reyes-García. 2017. Local ecological knowledge among Baka children: A case of ‘children’s culture’? *Journal of Ethnobiology* 37(1): 60–80.
- Gallois, S., T. Heger, T. van Andel, B. Sonké, and A.G. Henry. 2020. From bush mangoes to bouillon cubes: Wild plants and diet among the Baka, forager-horticulturalists from Southeast Cameroon. *Economic Botany* 74 (1): 1–13.
- Harris, D. 1996. A revision of the Irvingiaceae in Africa. *Bulletin du jardin botanique national de Belgique* 65(1/2):143–96. <https://doi.org/10.2307/3668184>.
- Hawthorne, W.D. and C. Jongkind. 2006. Woody plants of Western African forests. A guide to the forest trees, shrubs and lianes from Senegal to Ghana. Royal Botanic Gardens, Kew.
- Hladik, C.-M. 1996. Composition biochimique des fruits et perception gustative: Interactions et tendances évolutives dans les forêts tropicales. In: *L’alimentation en forêt tropicale. Intercations bioculturelles et perspectives de développement*, eds C.-M. Hladik, A. Hladik, H. Pagezy, O. F. Linares, G.J.A. Koppert, and A. Froment, 145–64. Paris: UNESCO editions.
- Ichikawa, M. 1996. Déterminismes écologiques et culturels des choix alimentaires des chasseurs-cueilleurs Mbuti Du Zaire. In: *L’alimentation en forêt tropicale. Intercations bioculturelles et perspectives de développement*, eds C.-M. Hladik, A. Hladik, H. Pagezy, O.F. Linares, G.J.A. Koppert, and A. Froment, 759–70. Paris: UNESCO editions.
- Ingram, V. 2014. Win-wins in forest product value chains? How governance impacts the sustainability of livelihoods based on non-timber forest products from Cameroon. Leiden: African Studies Centre.
- Ingram, V. and J. Schure. 2010. Review of non timber forest products (NTFPs) in Central Africa. Yaoundé: CIFOR.
- Ingram, V., M. Ewane, L. Njie Ndumbe, and A. Awono. 2017. Challenges to governing sustainable forest food: *Irvingia* spp. from Southern Cameroon. *Forest Policy and Economics* 84: 29–37. <https://doi.org/10.1016/j.forpol.2016.12.014>.
- Joiris, D.V. 1996. Ce que ‘bien manger’ veut dire chez les pygmées Kola (Gyeli) et Baka du sud-Cameroun. In: *Bien manger et bien vivre. Anthropologie alimentaire et développement en Afrique intertropicale*, eds A. Froment, I. de Garine, C. Binam Bikoi, and J. Loung, 365–70. Paris, ORSTOM: L’Harmattan.
- Kenfack, D., D.W. Thomas, G. Chuyong, and R. Condit. 2007. Rarity and abundance in a diverse African forest. *Biodiversity and Conservation* 16(7):2045–74.
- Kitanishi, K. 1994. The exchange of forest products (*Irvingia* nuts) between the Aka hunter-gatherers and the cultivators in northeastern Congo. *Tropics* 4(1):79–92.
- Ladipo, D. 2000. Harvesting of *Irvingia gabonensis* and *Irvingia wombulu* in Nigerian forests;

- potentials for the development of sustainable systems. In: Harvesting of non-wood forest products. Joint FAO/ECE/ILO Committee on forest technology, management and training, 325–34. Turkey.
- Leclerc, C. 2012. L'adoption de l'agriculture chez les pygmées Baka du Cameroun, dynamique sociale et continuité structurale. Paris/Versailles: MSH/Quae.
- Letouzey, R. 1976. Contribution de la botanique au problème d'une éventuelle langue pygmée. Vol. 57. Peeters Publishers.
- Levang, P., G. Lescuyer, D. Noubissi, C. Déhu, and L. Brousolle. 2015. Does gathering really pay? Case studies from forest areas of the east and south regions of Cameroon. *Forest, Trees and Livelihoods* 24(2): 128–143.
- Lowe, A.J., A.C.M. Gillies, J. Wilson, and I.K. Dawson. 2000. Conservation genetics of bush mango from Central/West Africa: Implications from random amplified polymorphic DNA analysis. *Molecular Ecology* 9(7):831–41. <https://doi.org/10.1046/j.1365-294x.2000.00936.x>
- N'Guessan, K., M.-T. Kouamé-N'Dri, C. Assi-Kaudjhis, and C.-B. Aké. 2015. Ethnobotanical study of spontaneous wild plants used for food by Krobou people in the south of Côte d'Ivoire. *Journal of Global Biosciences* 4(2):1354–65.
- Ndoye, O., M. Ruiz-Pérez, and A. Eyebe. 1997. The markets of non-timber forest products in the humid forest zone of Cameroon. London: UK.
- Ngansop, T. M., E.H. Biye, F.E. Fongnzossie, P.F. Forbi, and D.C. Chimi. 2019. Using transect sampling to determine the distribution of some key non-timber forest products across habitat types near Boumba—Bek national park, Southeast Cameroon. *BMC Ecology* 1–10. <https://doi.org/10.1186/s12898-019-0219-y>
- Pagezy, H. 1982. Seasonal hunger, as experienced by the Oto and the Twa of a Ntomba village in the equatorial forest (Lake Tumba, Zaire). *Ecology of Food and Nutrition* 12(3):139–153.
- Phillips, O. and A. H. Gentry. 1993. The useful plants of Tambopata, Peru: I. Statistical hypotheses tests with a new quantitative technique. *Economic Botany* 47 (1): 15–32.
- Popovich, D.G., D.J.A. Jenkins, C.W.C. Kendall, E.S. Dierenfeld, R.W. Carroll, N. Tariq, and E. Vidgen. 1997. The western lowland gorilla diet has implications for the health of humans and other hominoids. *Human and Clinical Nutrition* 2000–2005. <https://doi.org/10.1093/jn/127.10.2000>.
- Pyhälä, A. 2012. What future for the Baka? Indigenous people's rights and livelihood opportunities in South-east Cameroon. Finland: International Work Group for Indigenous Affairs and Plan.
- Sato, H., K. Kawamura, K. Hayashi, H. Inai, and T. Yamauchi. 2012. Addressing the wild yam question: How Baka hunter-gatherers acted and lived during two controlled foraging trips in the tropical rainforest of southeastern Cameroon. *Anthropological Science* 120(2): 129–49. <https://doi.org/10.1537/ase.110913>.
- Sonké, B. and T.L.P. Couvreur. 2014. Tree diversity of the Dja faunal reserve, Southeastern Cameroon. *Biodiversity Data Journal* 2:e1049. <https://doi.org/10.3897/BDJ.2.e1049>.
- Tchatat, M. and O. Ndoye. 2006. Étude des produits forestiers non ligneux d'Afrique Centrale: Réalités et perspectives. *Bois et Forêts Des Tropiques* 288(2):27–39. <https://doi.org/10.19182/bft2006.289.a20305>.
- Tchoundjeu, Z., A.R. Atangana, and A. Degrande. 2005. Indigenous methods in preserving bush mango kernels in Cameroon. *American Journal of Applied Sciences* 2(9):1337–42.
- Vihotogbé, R., N. Raes, R.G. van den Berg, B. Sinsin, and M.S.M. Sosef. 2019. Ecological niche information supports taxonomic delimitation of *Irvingia gabonensis* and *I. wombolu* (Irvingiaceae). *South African Journal of Botany* 127:35–42. <https://doi.org/10.1016/j.sajb.2019.08.025>.
- , R.G. Van den Berg, and M.S.M. Sosef. 2013. Morphological characterization of African bush mango trees (*Irvingia* species) in West Africa. *Genetic Resources and Crop Evolution* 60(4):1597–1614.
- Yasuoka, H. 2012. Fledging agriculturalists? Rethinking the adoption of cultivation by the Baka hunter-gatherers. *African Study Monographs. Supplementary Issue* 43(March):85–114. <https://doi.org/10.14989/153062>.